

23' - 3" FORMULA 233/160 H. P.
MERCUISER 160 TEST REPORT

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Figure #3.

100 h.p. Mercruiser Installation in 23' Formula.

1.

1. INTRODUCTION.

- 1.1. The purpose of this evaluation was to determine the overall performance of the 23' Formula 233 which was recently outfitted with 160 h. p. Mercruiser 160 engines and stern drive units. In addition, the results of this test also provides a basis for comparison between the Mercruiser 150's and 160's since both engine packages were evaluated in the 23' Formula in accordance with the same Test Procedure. Figures numbers 1 through 3 are photographs of the Formula with the dual 160 h. p. Mercruiser 160 engines and outdrives installed.
- 1.2. During the period of evaluation (28 August 1967 - 14 September 1967), 380 runs were made over a one-half (1/2) nautical mile test course.
- 1.3. All testing was performed in accordance with [REDACTED]
No. 1, Rev. A, dated 20 April 1966. 25X1A8a

2. DESCRIPTION OF 23' FORMULA 233.

- 2.1. The 23'-2" Thunderbird-Formula 233 is a reinforced fiberglass constructed, deep "V" hull, presently powered by dual 160 h. p. Mercruiser 160 engines and outdrive units.
- 2.2. The craft is a ruggedly constructed boat capable of carrying heavy 25X1C10b [REDACTED] payloads for relatively long distances in unfavorable sea conditions. A list of principle dimensions and specifications for the Formula 233 is provided below:

2.

Centerline Length	23' - 3"
Beam	8' - 0"
Fuel Capacity	160 gals. (two 80-gal. tanks)
Weight	5,280 pounds
Power Package	Dual 160 h. p. Mercruiser 160 engines and outdrives.

3. GENERAL DESCRIPTION OF MERCRUISER "160" MARINE ENGINE.

- 3.1. The 160 h. p. Mercruiser Marine "160" is a six-cylinder, in-line, overhead valve engine. This particular engine uses hydraulic valve lifters and hollow push rods to operate the individually mounted rocker arms which pivot on ball seats.
- 3.2. A gear-type oil pump, driven by the distributor shaft, provides full pressure lubrication for each of these engines. The main oil gallery along hydraulic lifter areas passes oil through drilled passages to each cam and main bearing, through the hydraulic lifters and hollow push rods to the rocker arms.
- 3.3. The list of specifications for the Marine Engine is tabulated below:

Horsepower	160
Number of Cylinders	6 (in-line)
Bore	3.875"
Stroke	3.531"
Firing Order (Front to Rear)	1-5-3-6-2-4
Number of Main Bearings	7
Displacement	250 cubic inches
Timing at 500 - 550 RPM	6° BTC

Point Gap	0.016"
Recommended Operating RPM	3,900 - 4,300
Type Engine	In-Line, Valve in Head
Compression Pressure	140 PSI
Idle Speed	500 600 RPM
Plug Gap	0.035"
Cam Angle	31° - 34°
Thermostat	143° F.

4. COMPARISON BETWEEN MERCUISER 150 AND MERCUISER 160 MARINE ENGINES.

- 4.1. The design of the Mercruiser 150 and 160 engines is essentially the same except that the stroke of the Mercruiser 160 is 3.531" as compared to 3.250" for the Mercruiser 150. As a result, certain of the Mercruiser 160 components differ from the 150 due to the increased piston stroke and horsepower of the Marine "160" engine. For example, the block and the crankshaft of the 160 engines are slightly larger than those in the 150's. Even though both engines are slightly different, many of the Mercruiser 150 and 160 components are interchangeable.
- 4.2. It is also noted that the carburetion of both engines is essentially the same.
- 4.3. Although these engines have many similarities, it is not feasible to upgrade the horsepower of the Mercury 150 engine to 160 h.p. by increasing the piston's stroke, due to the expense involved.
- 4.4. Appendix A provides a list of specifications comparing both the Mercruiser 150 and 160 marine engines.

4.

4.5. In addition to installing larger horsepower engines in the Formula, the boat's transom was also modified in order to insure optimum craft performance. This modification involved lowering the outdrives on the transom 1/2 inch (refer to Figure No. 2) so that their cavitation plates were located 1/4 inch above the boat's bottom when measured along the vertical centerline of each outdrive.

5. DESCRIPTION OF PERFORMANCE TEST.

- 5.1. After the engine manufacturer's recommended break-in period was satisfied and both engines tuned in accordance with applicable operating instructions, calibrated Ongaro Model Mk. 21 Fuel Flow Meters (rated at 20 gph capacity) were installed.
- 5.2. The 23' Formula 233 was operated over a one-half (1/2) nautical mile test course at various engine RPM's (2,000, 2,500, 3,000, 4,000 and full throttle) while carrying from 0 to 3,000 pounds added payload in 1,000 pound increments.
- 5.3. The evaluation involved determining the boat's optimum level of performance (maximum speed and range) for each loading condition, by investigating twenty (20) propeller size and outdrive pin position combinations.
- 5.4. During the course of the test, all outdrive pin positions (one (1) through five (5)) and the following propeller sizes were investigated:

Three Bladed Aluminum, 15-1/2" diameter x 19" pitch.

Three Bladed Aluminum, 15" diameter x 21" pitch.

Three Bladed Aluminum, 14-1/2" diameter x 23" pitch.

Three Bladed Aluminum, 14-1/2" diameter x 25" pitch.

5.

- 5.5. Comparing all of the above combinations for each loading condition, revealed the set of propellers and the outdrive pin positions which results in optimum craft performance for a particular range of payloads.

6. TEST RESULTS.

- 6.1. The following provides a brief summary of the boat's optimum levels of performance for each loading condition. It is noted that the boat was fully fueled and operated by two (2) men throughout the test:

6.1.1. No Load (Also refer to Appendices B and C-1).

Propeller Size:	14-1/2" dia. x 23" pitch.
Outdrive Pin Position:	2
Full Throttle Results:	
RPM	4,200
Speed	38.1 Knots (maximum for test)
Range	203 Nautical miles.
Economy Cruise Results:	
RPM	3,000
Speed	29.3 Knots
Range	293 Nautical miles (maximum for test).

6.1.2. 1,000 Lbs. Added Payload (Also refer to Append. B & C-2).

Propeller Size:	15" diameter x 21" pitch.
Outdrive Pin Position:	1
Full Throttle Results:	
RPM	4,450
Speed	34.6 Knots
Range	173 Nautical miles.
Economy Cruise Results:	
RPM	3,000
Speed	23.7 Knots
Range	207 Nautical miles.

6.1.3. 2,000 Lbs. Added Payload (Also refer to Append. B & C-3).

Propeller Size: 15" diameter x 21" pitch.

Outdrive Pin Position: 1

Full Throttle Results:

RPM 4,075

Speed 32.5 Knots

Range 173 Nautical Miles.

Economy Cruise Results:

RPM 3,250

Speed 24.4 Knots

Range 194 Nautical miles.

6.1.4. 3,000 Lbs. Added Payload (Also refer to Append. B & C-4).

Propeller Size: 15-1/2" diameter x 19" pitch.

Outdrive Pin Position: 1

Full Throttle Results:

RPM 4,350

Speed 29.8 Knots

Range 159.5 Nautical miles.

Economy Cruise Results:

RPM 3,875

Speed 26.7 Knots

Range 177 Nautical miles.

7. COMPARISON OF MERCUISER 150 VS 160 TEST RESULTS ON 23' FORMULA 233.

7.1. Using the combined horsepower of both engines as a common denominator, the following comparisons are made between the performance of the Mercruiser 150 and Mercruiser 160 engines. It is noted that these comparisons are made at full throttle conditions only, since it is assumed that at this level of operation both the Mercruiser 150 and 160 engines are operating at their rated horsepowers (i. e. , 150 and 160 horsepower respectively).

7.1.1. Speed Comparison (Knots/Horsepower).

Added Load	Mercruiser 150	Mercruiser 160	% Increase In Speed (Kts/Hp)
0 Lbs	0.120 knots/hp	0.119 knots/hp	0.83% (decrease)
1,000 Lbs	0.1065 knots/hp	0.108 knots/hp	1.41%
2,000 Lbs	0.090 knots/hp	0.1015 knots/hp	12.80%
3,000 Lbs	0.87 knots/hp	0.93 knots/hp	6.90%

7.1.2. Fuel Consumption Comparison (Gal./Hp - Hr).

Added Load	Mercruiser 150	Mercruiser 160	% Increase in Fuel Consumption (Gal / Hp - Hr)
0 Lbs	0.093 gal/hp-hr	0.094 gal/hp-hr	1.08%
1,000 Lbs	0.093 gal/hp-hr	0.100 gal/hp-hr	7.55%
2,000 Lbs	0.087 gal/hp-hr	0.094 gal/hp-hr	8.05%
3,000 Lbs	0.083 gal/hp-hr	0.094 gal/hp-hr	13.2%

7.1.3. Range Comparison (Nautical Miles).

Added Load	Mercruiser 150	Mercruiser 160	% Decrease In Range (Naut Mi/Hp)
0 Lbs	0.685 Naut Mi/Hp	0.635 Naut Mi/Hp	7.3%
1,000 Lbs	0.610 Naut Mi/Hp	0.540 Naut Mi/Hp	11.4%
2,000 Lbs	0.555 Naut Mi/Hp	0.540 Naut Mi/Hp	2.71%
3,000 Lbs	0.555 Naut Mi/Hp	0.498 Naut Mi/Hp	10.25%

NOTE: Curves of the above comparisons which are made on a per horsepower basis are shown in Appendix D.

7.2. As expected, the increased horsepower of the Mercruiser 160, when compared to the Mercruiser 150, results in an increase in both speed and fuel consumption and a decrease in range. It is noted, however, that in the 2,000 pound load range, there is a significant improvement in the boat's load carrying capability with the 160 h. p. engines.

7.3. Comparing the actual performance results of the Mercruiser 160's to the Mercruiser 150's, clearly indicates that the load carrying capability of the Formula with the 160's is considerably improved. The following comparisons are made at full throttle conditions only. (Refer to Appendices C-1 through C-4 and Appendix E for a complete comparative performance analysis between the two engines.)

7.3.1. Speed (Knots).

Added Load	Mercruiser 150	Mercruiser 160	%Increase in Actual Speed
0 Lbs	36.0 Knots	38.1 Knots	5.63%
1,000 Lbs	32.0 Knots	34.0 Knots	8.14%
2,000 Lbs	27.0 Knots	32.5 Knots	20.4%
3,000 Lbs	26.0 Knots	29.8 Knots	14.6%

7.3.2. Fuel Consumption (Gallons/Hour).

Added Load	Mercruiser 150	Mercruiser 160	% Increase In Actual Fuel Consumption
0 Lbs	28 Gal/Hr	30 Gal/Hr	7.15%
1,000 Lbs	28 Gal/Hr	32 Gal/Hr	14.2%
2,000 Lbs	26 Gal/Hr	30 Gal/Hr	15.4%
3,000 Lbs	25 Gal/Hr	30 Gal/Hr	20.0%

7.3.3. Range (Nautical Miles).

Added Load	Mercruiser 150	Mercruiser 160	% Decrease In Range
0 Lbs	206 Nautical miles	203 Nautical Miles	1.46%
1,000 Lbs	182.2 Naut. miles	173.0 Naut. miles	5.04%
2,000 Lbs	166.2 Naut. miles	173.0 Naut. miles	4.1% (Increase)
3,000 Lbs	166.2 Naut. miles	159.5 Naut. miles	4.03%

9.

The comparative results also indicate a definite increase in performance of the 160's over the 150's. The results show an overall average increase in speed of 12.19% and an overall average decrease in range of only 1.61% for the various loading conditions evaluated. As mentioned previously, the Formula's major area of improvement in overall performance is found in its load carrying capability. This, of course, is attributable to the Mercruiser 160 installation, coupled with lowering the stern drive approximately 1/2" on the transom.

7.4. However, it should not be concluded that the Mercruiser 160 installation alone is totally responsible for the boat's increased performance. The transom modification discussed in paragraph 4.5. above also accounts for a portion of this increase. It should be recognized that the degree to which each contributed to the increased performance cannot be measured quantitatively.

8. CONCLUSIONS.

8.1. Based on the performance test and comparative results, the following conclusions are drawn:

- a. The Formula's load carrying capability, particularly in the 2,000 pound payload range, has improved considerably.

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- b. The additional 6.67% increase in horsepower of the Mercruiser 160's over the 150's has resulted in an overall average increase in speed of 12.19%, and an overall average decrease in range of 1.61% for the various loading conditions evaluated.

NOTE: It should not be concluded that the increased horsepower of the Mercruiser 160 engines alone is totally responsible for the boat's increased performance. Lowering the outdrives 1/2" on the transom also accounts for a portion of this increase. The degree to which each contributed to the increased performance cannot be measured quantitatively.

- c. A maximum speed of 38.1 knots was achieved when the boat was fully fueled and operated at full throttle without an added payload. The range of the boat while operating under these conditions is 203 nautical miles.
- d. The maximum range of the boat, 293 nautical miles, was achieved when the boat was fully fueled and operated at 3,000 RPM without an added payload. The speed of the boat under these conditions was 29.3 knots.
- e. Conclusions in regard to the Formula's seakeeping ability and rough water operation will be provided upon completion of the comparative trials between the Formula and the Hobbs Boat. The comparative trials, which will be performed in accordance with [REDACTED] dated 20 October 1966, will involve operating the Formula and the Hobbs Boat (both outfitted with 160 h. p. Mercruiser engines) over a thirty (30) nautical mile test course under unfavorable sea conditions.

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- f. The maximum speed of the Hobbs Boat with the Mercruiser 150 engines installed still exceeds that of the Formula with the Mercruiser 160's by two-tenths (0.2) of a knot.

9. RECOMMENDATIONS.

- 9.1. Recommendations in regard to the Mercruiser 160's installation in the 23' Formula will not be made until completion of the comparative trials discussed in paragraph 8.1. e. above.

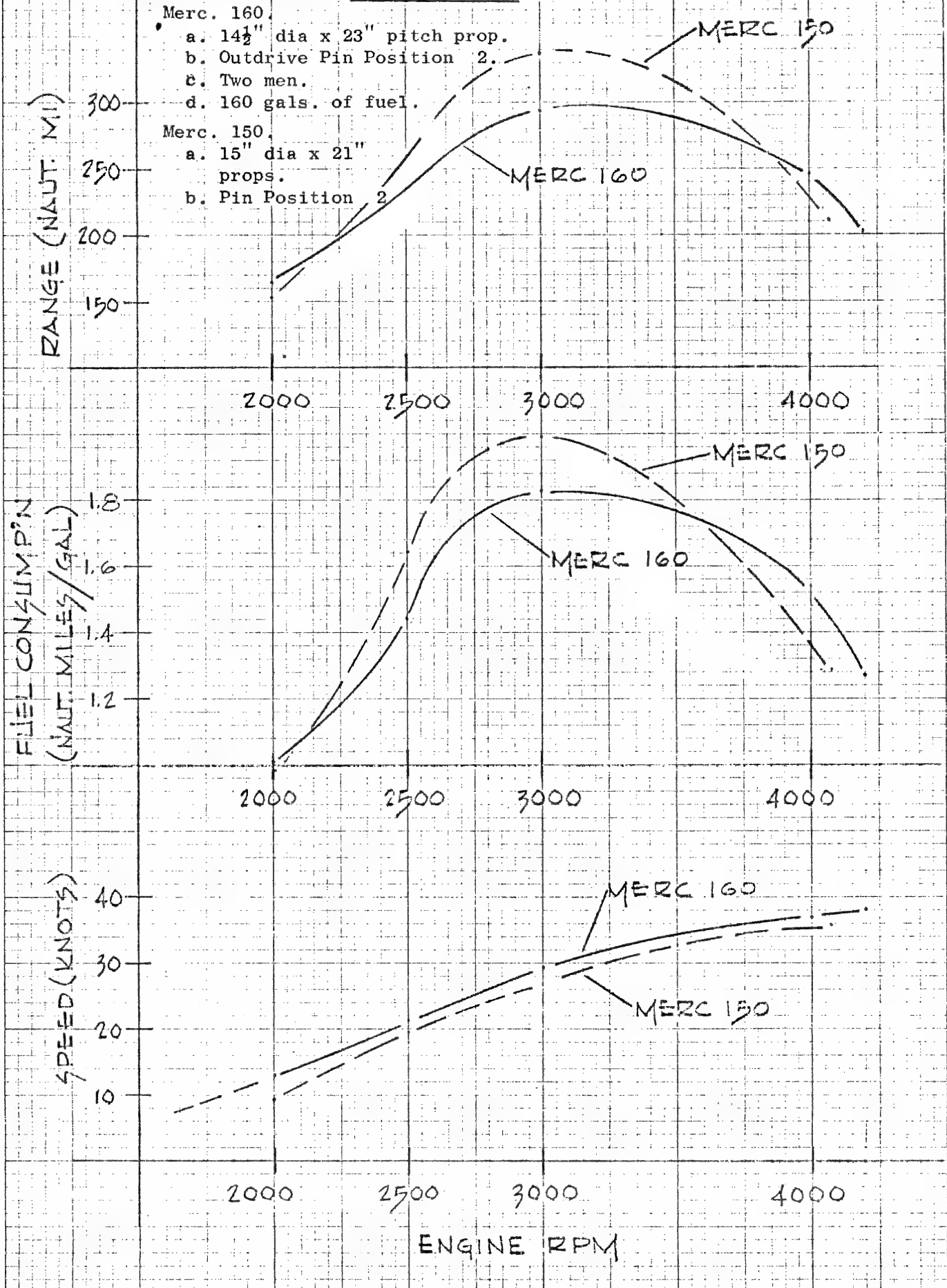
APPENDIX A -- SPECIFICATIONS FOR MERCURISER 150 AND 160 MARINE ENGINES.

Engine Model	Mercruiser 150	Mercruiser 160
Type Engine	In-Line, Valve-In-Head	M/C 160
Stern Drive Unit for Power Package	M/C - 1C	6 In-Line
Number of Cylinders	6 In-Line	1-5-3-6-2-4
Firing Order, Front to Rear	1-5-3-6-2-4	500 - 600
Idle RPM	500 - 600	3,900 - 4,300
Operating RPM	3,900 - 4,300	160
Horsepower	150	3.875
Bore (Inches)	3.875	3.531
Stroke (Inches)	3.250	250
Piston Displacement (Cubic Inches)	230	140
Compression Pressure (PSI)	140	7
Number of Main Bearings	7	1.7:1
Gear Ratio	1.7:1	One Two-Barrel
Carburetion	6° BTC	6° BTC
Timing at 500 - 550 RPM	AC C-44-N	AC C-44-N
Spark Plug	0.035"	0.035"
Plug Gap	31° - 34°	31° - 34°
Cam Angle	Cold Water Feed Pump and Warm	
Cooling	Recirculating Pump	
Valve Lifters	Hydraulic	Hydraulic
Generator	32 Amp Marine Alternator	
Length (Transom to Front of Engine - Inches)	41-19/32	41-19/32
Depth Below Driveshaft Centerline -(Inches)	7-1/2	7-1/2
Height Above Driveshaft Centerline -(Inches)	20-9/16	20-7/8
Engine Suspension	Three Point Rubber Mounted	
Propeller Drive	Shearproof Spline (No Shear or Drive Pins)	
Propeller Impact Protection	Flo-Torq Propeller Safety Clutch	
Propeller Rotation	Right Hand	Right Hand

APPENDIX B -- COMPARATIVE TEST RESULTS OF MERCURUISER 150's VS MERCURUISER 160's IN THE 23' - 3" FORMULA 233.

	Engine Model	Added Load (Pounds)			
		0	1,000	2,000	3,000
Propeller Size @ Full Throttle	Merc. 150 Merc. 160	15" x 21" 14-1/2" x 23"	15-1/2" x 19" 15" x 21"	15-3/4" x 17 15" x 21"	15-3/4" x 17 15-1/2" x 19
Outdrive Pin Position @ Full Throttle	Merc. 150 Merc. 160	3 2	2 1	1 1	1 1
Speed (Knots) at Full Throttle	Merc. 150 Merc. 160	36.0 38.1	32.0 34.0	27.0 32.5	26.0 29.8
Fuel Consumption at Full Throttle	Merc. 150 Merc. 160	28 gph 30 gph	28 gph 32 gph	26 gph 30 gph	25 gph 30 gph
Nautical Miles/gallon at Full Throttle	Merc. 150 Merc. 160	1.278 1.271	1.14 1.081	1.04 1.081	1.04 0.995
Cruising Radius at Full Throttle	Merc. 150 Merc. 160	103 101.5	91.1 86.5	83.1 86.5	83.1 79.75
Range at Full Throttle	Merc. 150 Merc. 160	206 203	182.2 173.0	166.2 173.0	166.2 159.5

TEST CONDITIONS: NO LOAD RESULTS.



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TEST CONDITIONS:

Merc. 160.

a. 15" dia. x 21" pitch props.

b. Outdrive Pin Position 1.

c. Two men

d. 160 gals. of fuel.

Merc. 150.

a. 15-3/4" dia x 17" pitch props.

b. Outdrive Pin Position 1.

RANGE (NAUTICAL MILES)

200

175

150

125

2000

2500

3000

4000

MERC 160

MERC 150

FUEL CONSUMPTION
(NAUTICAL MILES/GAL)

1.3

1.1

0.9

0.7

2000

2500

3000

4000

MERC 160

MERC 150

SPEED (KNOTS)

40

30

20

10

2000

2500

3000

4000

MERC 160

MERC 150

ENGINE RPM

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3,000 POUND LOAD CONDITIONS

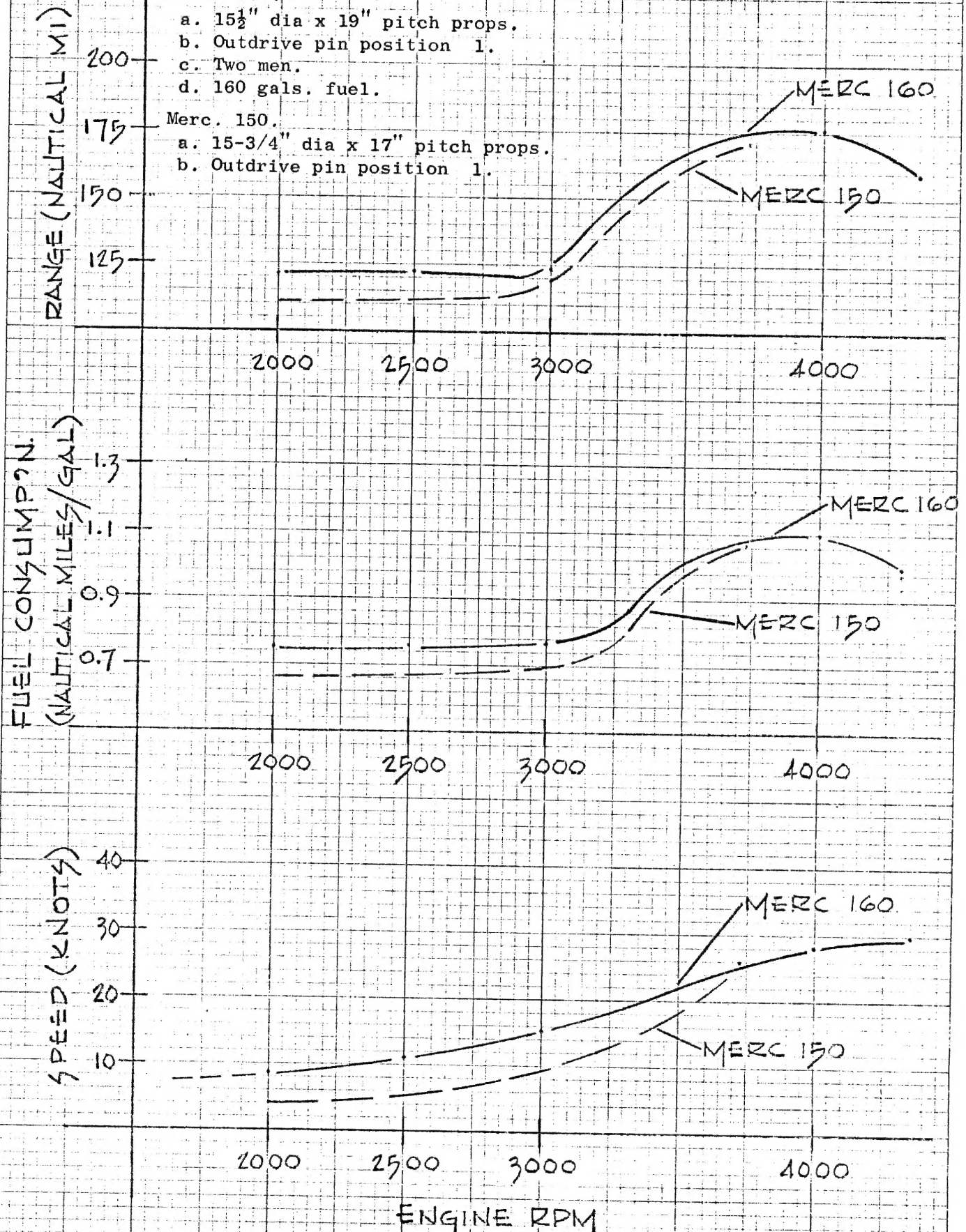
TEST CONDITIONS:

Merc. 160.

- a. $15\frac{1}{2}$ " dia x 19" pitch props.
- b. Outdrive pin position 1.
- c. Two men.
- d. 160 gals. fuel.

Merc. 150.

- a. $15\frac{3}{4}$ " dia x 17" pitch props.
- b. Outdrive pin position 1.

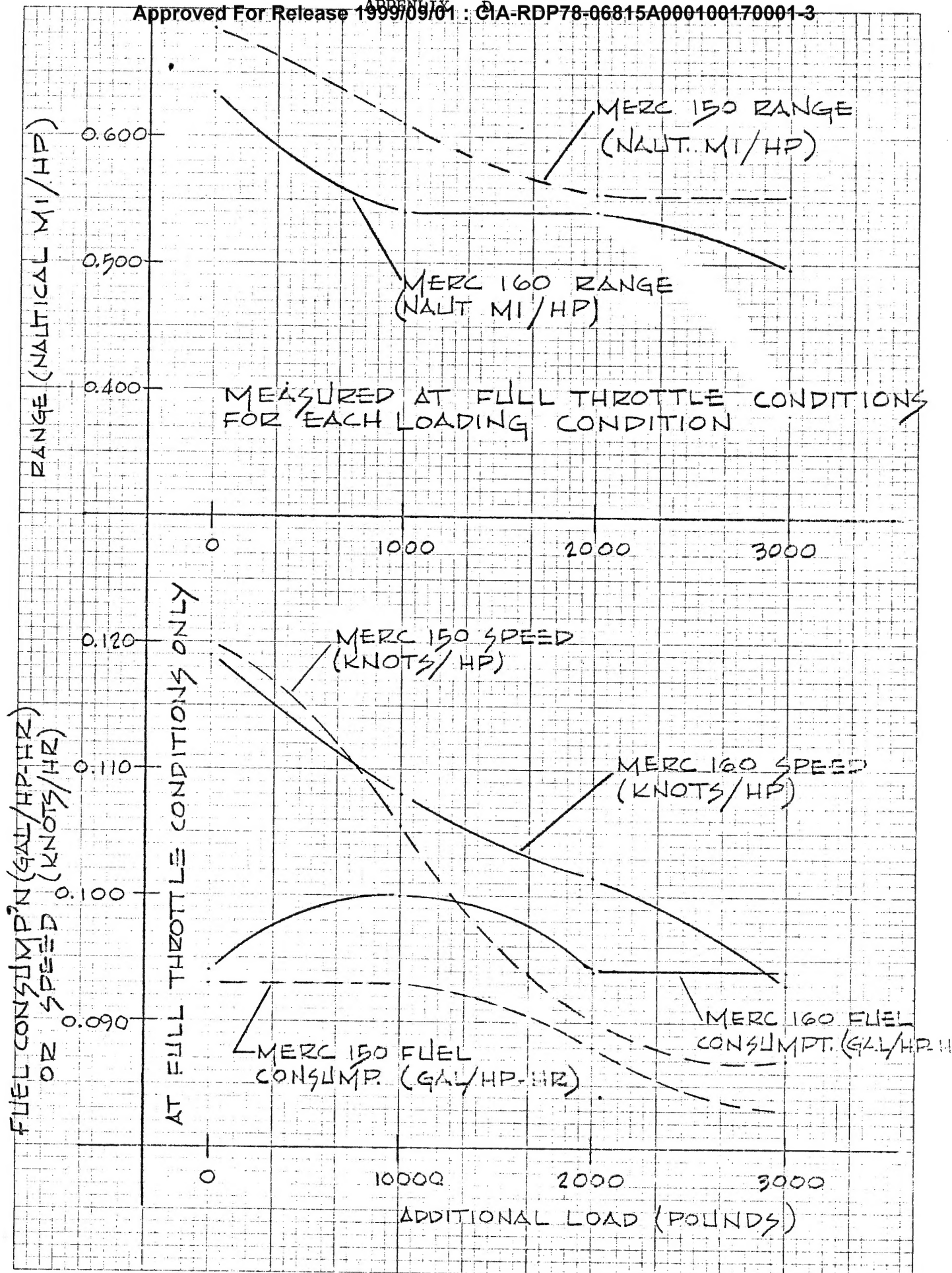


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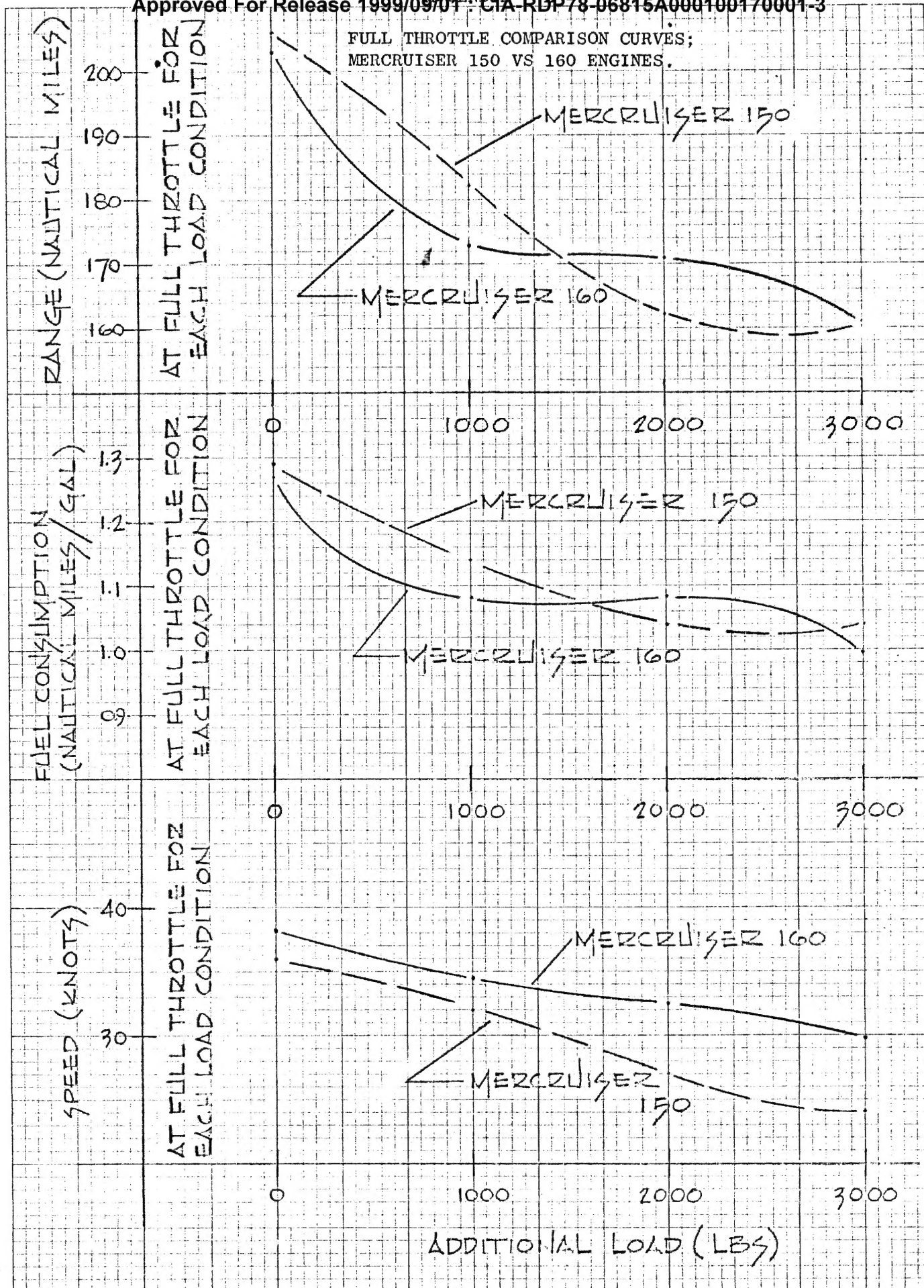
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APPENDIX F



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